United States Environmental Protection Agency

Understanding Life Cycle Assessment: Applications for OSWER's Land and Materials Management

Sept 23, 2009

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September 21, 2009

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Format

- What is LCA?
- What steps are involved in conducting one?
- What do we need to know about LCIA?
- Why use TRACI?
- What do we know about weighting?
- How would this look for a green remediation site?

What is an LCA?

- Typically it is an evaluation of a product or service on a functional unit basis over the full life cycle, including:
  - –Raw materials
  - –Transportation
  - –Manufacturing (including suppliers)
  - –Use
  - –Recycle or Disposal

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How can an LCA for remediation be conducted?

- For remediation, this can be evaluation of clean-up to a specified level over the full life cycle, including the same above steps for all goods and services which are utilized in the clean-up phase.
- Separate and independent analyses which may be considered during decision making include:
  - The clean up schedule, if this is not consistent for the various remediation options.
  - The cost of remediation.
  - Public perception or other influencing factors.

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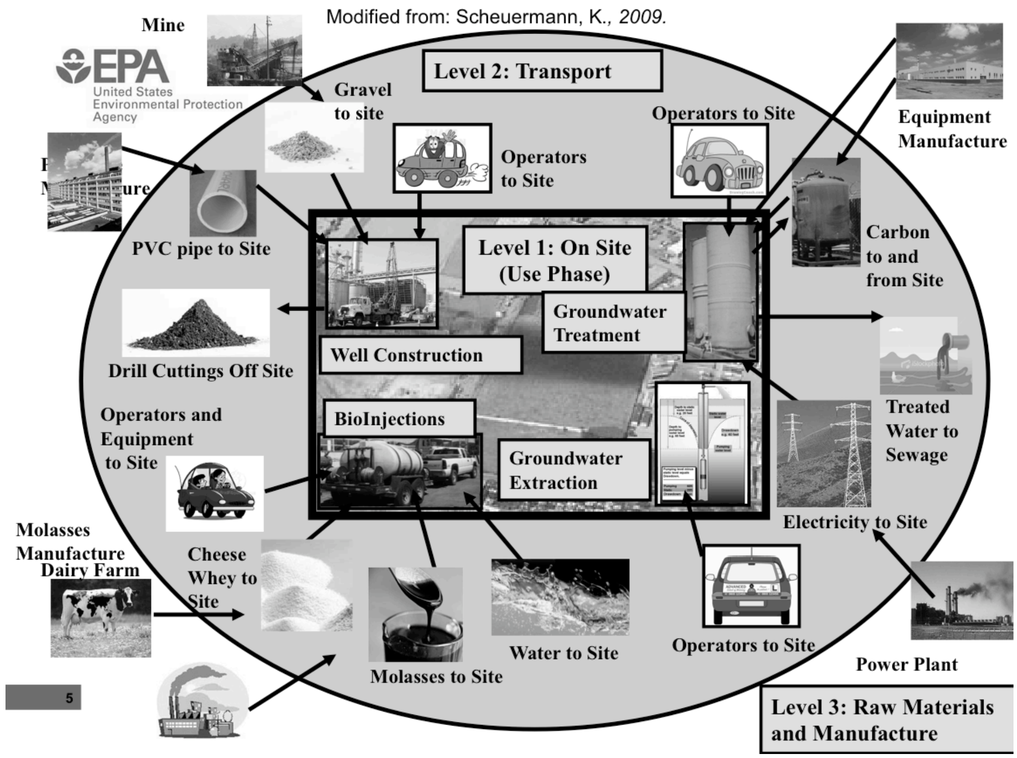
Modified from: Scheuermann, K., 2009.
Mine
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Level 2: Transport
Gravel to site
Operators to Site
Operators to Site
Equipment Manufacture
PVC pipe to Site
Level 1: On Site (Use Phase)
Carbon to and from Site
Groundwater Treatment
Drill Cuttings Off Site
Well Construction
Operators and Equipment to Site
BioInjections
Treated Water to Sewage
Groundwater Extraction
Electricity to Site
Molasses Manufacture
Dairy Farm
Cheese Whey to Site
Water to Site
Operators to Site
Power Plant
Molasses to Site
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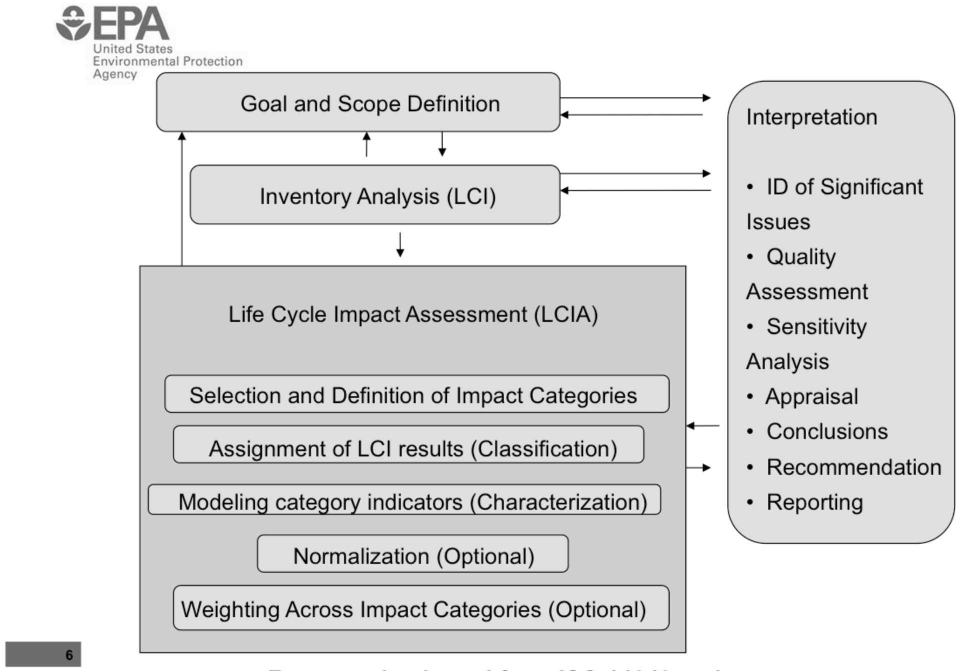
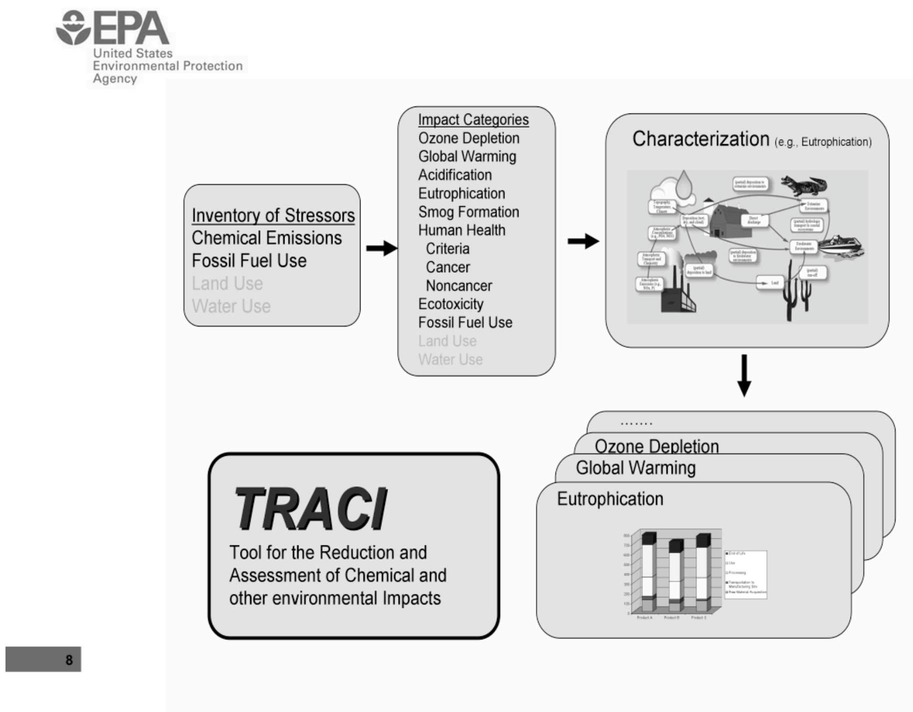
Level 3: Raw Materials and Manufacture



Framework adapted from ISO 14040 series

TRACI – Tool for the Reduction and Assessment of Chemical and other environmental Impacts

- TRACI is an impact assessment tool which allows the characterization of impacts for LCA, sustainability metrics, process design, facility level analysis, or company level analysis.
- It was developed for use in the US with site-specific characterization for several impact categories.
- Users need to provide emissions data and resource use data to develop an impact assessment.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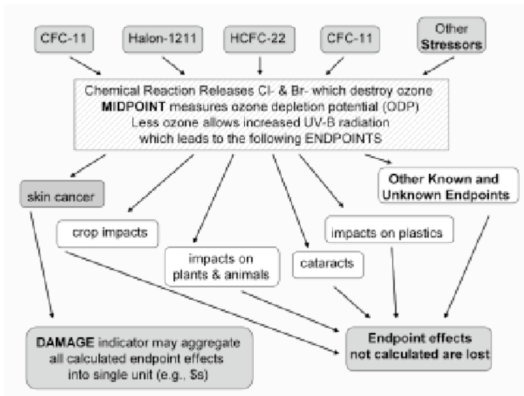
Inventory of Stressors
Chemical Emissions
Fossil Fuel Use
Land Use
Water Use
Impact Categories
Ozone Depletion
Global Warming
Acidification
Eutrophication
Smog Formation
Human Health
Criteria
Cancer
Noncancer
Ecotoxicity
Fossil Fuel Use
Land Use
Water Use
Characterization (e.g., Eutrophication)
....
Ozone Depletion
Global Warming
Eutrophication
TRACI
Tool for the Reduction and
Assessment of Chemical and
other environmental Impacts
8

Best Decision Points



Midpoint analysis (e.g., ODP, GWP) for ozone depletion, global warming, acidification, eutrophication, and smog formation allows maximum comprehensiveness & scientific defensibility, and minimal value choices & modeling assumptions.

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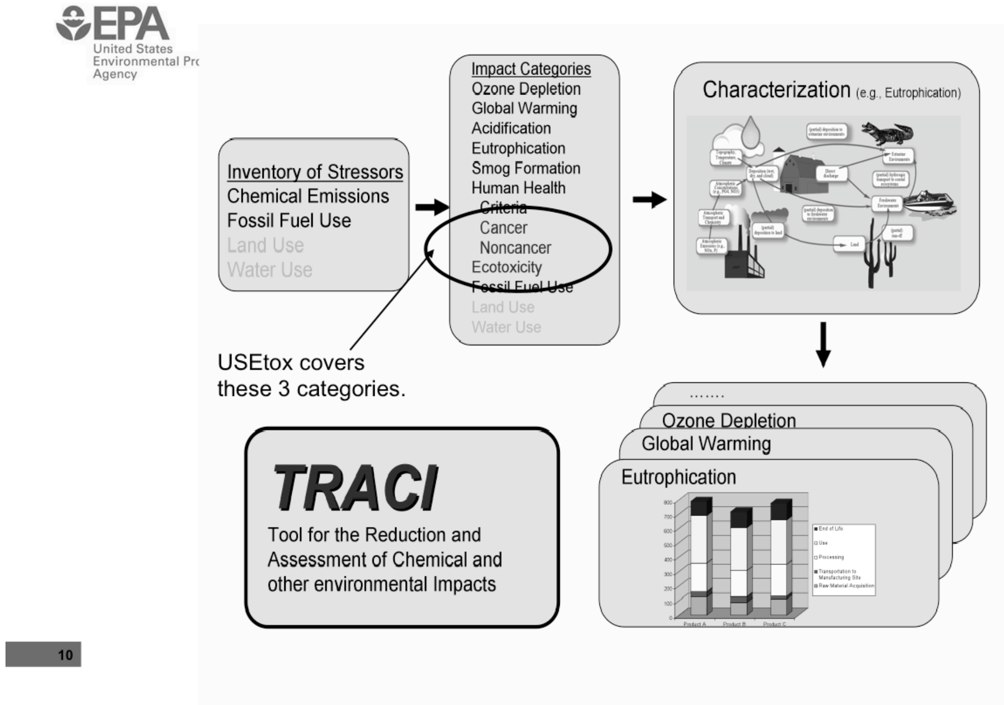
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Characterization (e.g., Eutrophication)
USEtox covers
these 3 categories.
TRACI
Tool for the Reduction and
Assessment of Chemical and
other environmental Impacts
....
Ozone Depletion
Global Warming
Eutrophication
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Human Health Modeling

- CalTOX was recognized as the most sophisticated model for risk assessment while TRACI was being developed.
- Original TRACI based on CalTOX work which uses EPA's Risk Assessment Guidelines and Human Exposure Factor Handbook.
- Provided 23 human exposure pathways with multimedia modeling and Crystal Ball link to allow parameter uncertainty and variability analysis.

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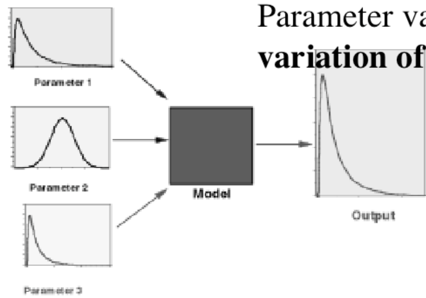
Parameter Uncertainty & Variability Analysis

Parameter variability: **natural variation of input parameters**



Parameter uncertainty: **random, systematic, and measurement errors**

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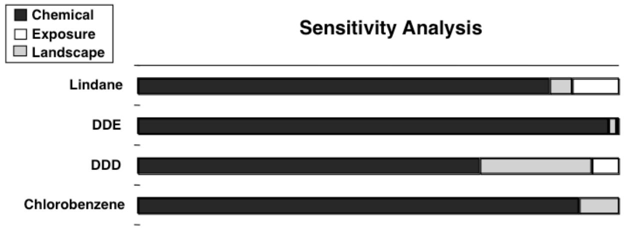
Parameter Uncertainty & Variability Analysis

Modified from: Hertwich, E., et al, *Parameter uncertainty and variability in evaluative fate and exposure models.* Risk Analysis, 1999. 19.



Probabilistic research within CALTOX showed that for the majority of the TRI substances chemical data (e.g., toxicity and half life) had the biggest impact on data variability/uncertainty.

This research also supported the theory that toxicity characterization factors could be global.

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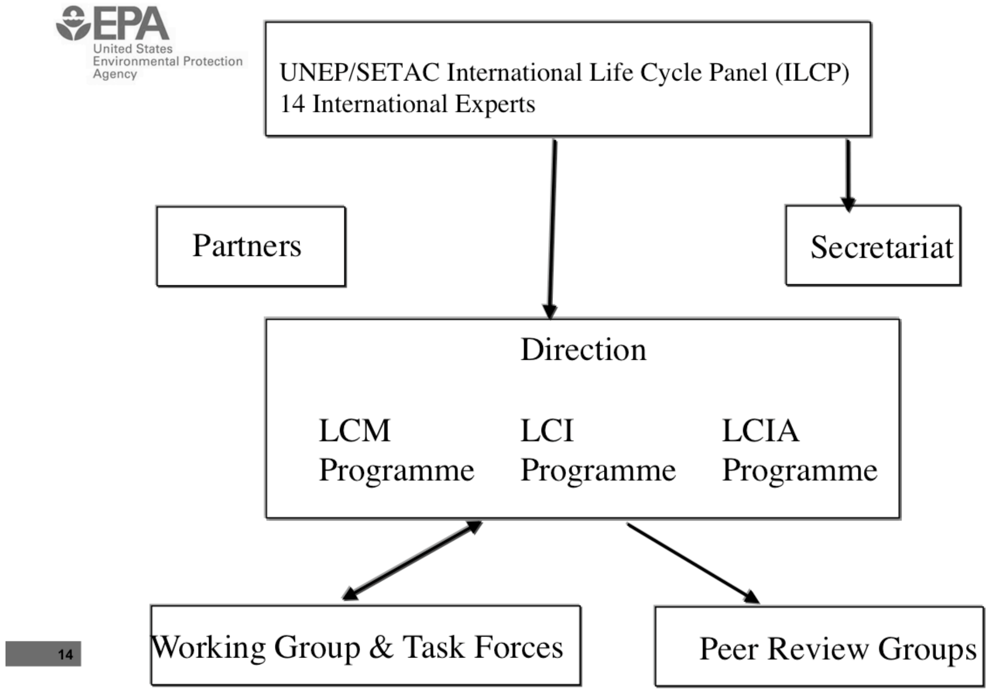
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UNEP/SETAC International Life Cycle Panel (ILCP)
14 International Experts
Partners
Secretariat
Direction
LCM Programme
LCI Programme
LCIA Programme
Working Group & Task Forces
Peer Review Groups
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Human Health Modeling

- TRACI uncertainty and variability analysis supports the theory that a single model can provide representation of human health cancer and noncancer globally.
- Tom McKone and Edgar Hertwich were crucial in TRACI human health cancer, noncancer, and ecotoxicity modeling. Tom has also been involved in USEtox development.
- USEtox has not yet made a complete USEtox spreadsheet available including data and results for metals.
- The US EPA plans to conduct a peer review of the complete USEtox when it is available.

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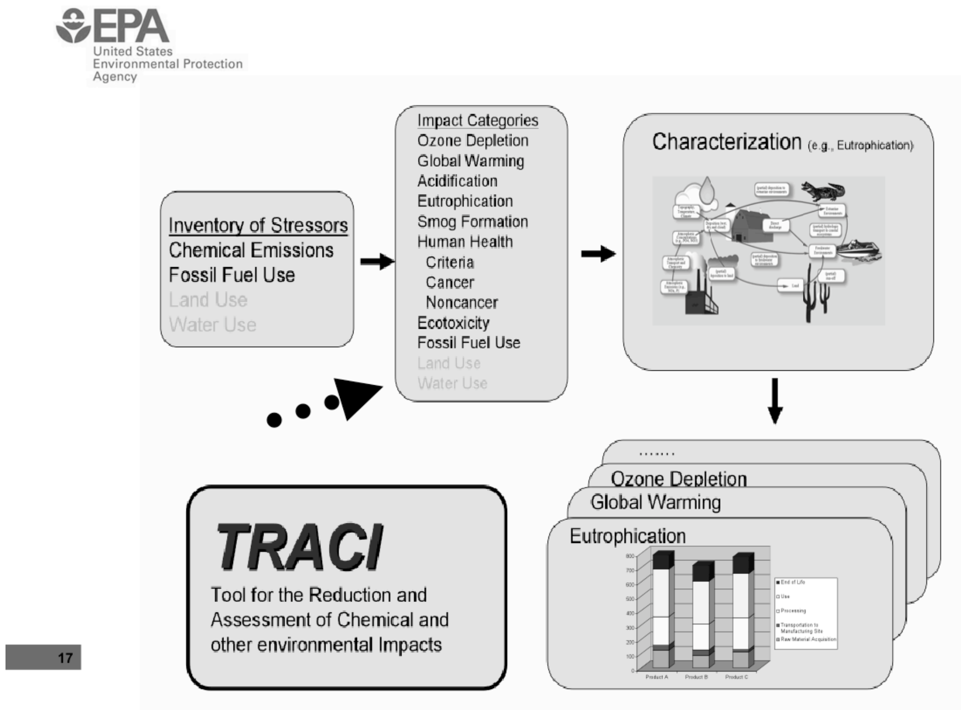
- A further description of the Life Cycle Initiative may be found at: http://www.uneptie.org/scp/lcinitiative/
- Early citations presenting the procedure for development of USEtox may be found at:
- Rosenbaum, R., et al, *USEtox - The UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity.* International Journal of Life Cycle Assessment, 2008. **7**: p. 532-546.
- Hauschild, M.Z., et al, *Building a Model Based on Scientific Consensus for Life Cycle Impact Assessment of Chemicals: The Search for Harmony and Parsimony* Environmental Science & Technology, 2008. **42**(19): p. 7032 - 7037.
- The current draft spreadsheet may be found at: USEtox.org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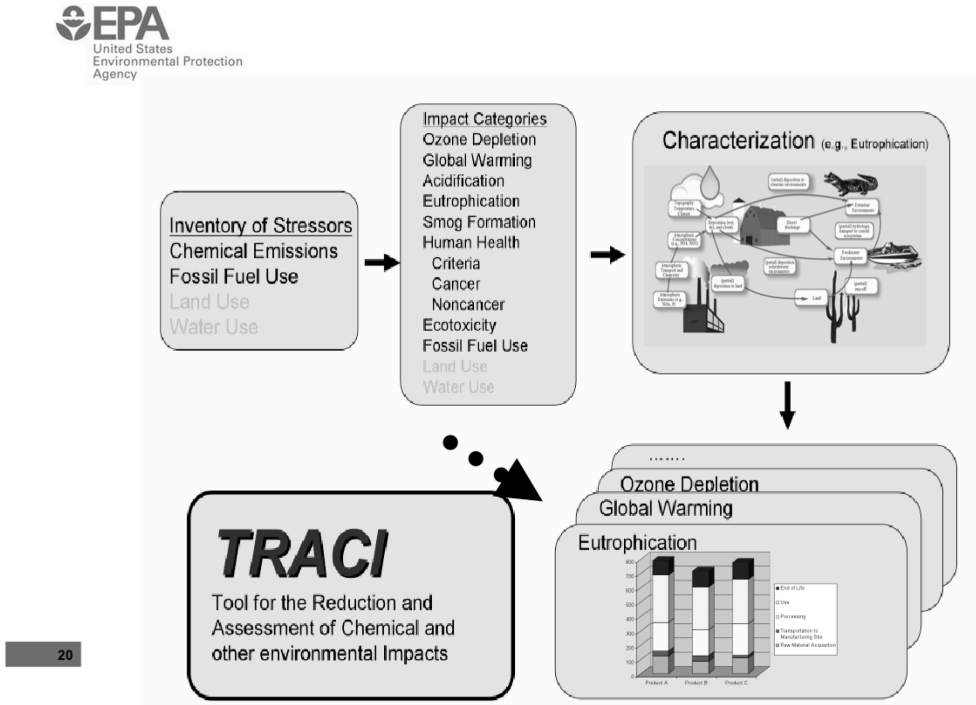
TRACI Status

- **US EPA Gold Medal recipient**.
- **US Green Building Council LEED** is using TRACI.
- **NIST** has incorporated TRACI into **BEES** (Building for Env. & Economic Sustainability) which is used by US EPA for Environmentally Preferable Purchasing.
- **US Marine Corps** incorporated TRACI into EKAT (Environmental Knowledge and Assessment Tool) for military & non-military uses.
- TRACI is incorporated into various LCA software**.**
- TRACI is included in sustainability standards (e.g., *NSF/ANSI 140 Sustainable Carpet Assessment Standard)*.
- Within college curriculum in engineering and design depts.
- Over 25,000 copies distributed.

TRACI References

- Further information and papers about TRACI may be found at:
  - Bare, J.C., et al, "TRACI – The Tool for the Reduction and Assessment of Chemical and other environmental Impacts," *Journal of Industrial Ecology*, Vol. 6, No. 3, 2003.
  - Bare, J.C., "Developing a Consistent Decision-Making Framework by Using the U.S. EPA's TRACI," AICHE Annual Meeting, Indianapolis, IN, 2002.
  - http://www.epa.gov/nrmrl/std/sab/traci/
- See the following paper for more details on midpoints and endpoints: Bare, J.C., et al (2000). "Life Cycle Impact Assessment Midpoints vs. Endpoints – The Sacrifices and the Benefits."
- A comparison of impact assessment methodologies is also available: Bare, J.C. and T.P. Gloria. (2006). "Critical Analysis of the Mathematical Relationships and Comprehensiveness of Life Cycle Impact Assessment Approaches."
- The full citation of these and related articles are at: http://www.epa.gov/ORD/NRMRL/std/sab/iam/
- You may contact me for more information or access: bare.jane@epa.gov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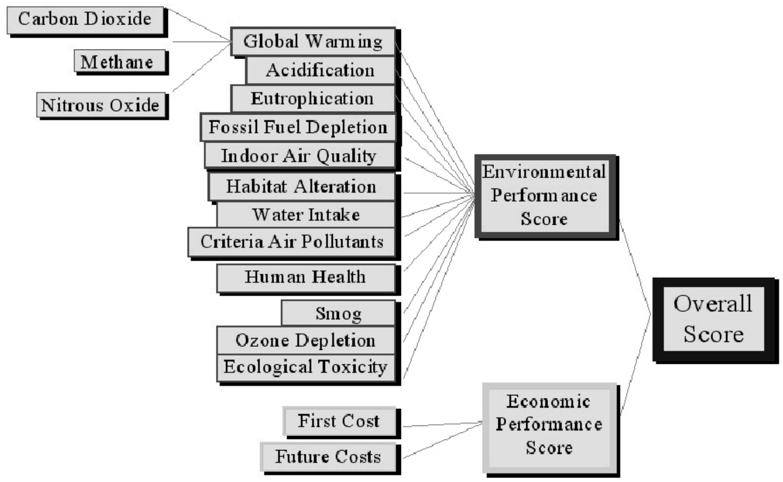
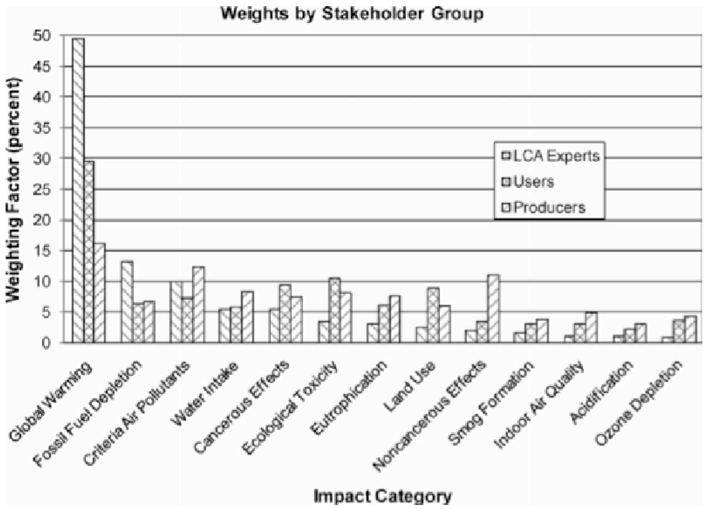
BEES 4.0



Information and access to BEES can be found at: http://www.bfrl.nist.gov/oae/software/bees/

NIST Weighting Workshop

- Categorization of stakeholders did matter.
- From Gloria, et al, *Life cycle impact assessment weights to support environmentally preferable purchasing in the United States.* Environmental Science & Technology, 2007. 41(21).



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LEED 2009 uses TRACI & NIST weighting

- See three attached PDFs:
  - LEED 2009 – Weightings Background.pdf
  - LEED 2009 – Weightings Overview.pdf
  - LEED 2009 – Weightings Tool Overview

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US GBC's LEED 2009 uses TRACI

- "LEED 2009 uses US EPA's TRACI… because they represent a comprehensive, currently available complement to LEED which is appropriate for the North American building market."
- "Layered on top of the TRACI environmental impact categories are weightings devised under the auspices of NIST…"
- "The workbook tool is a credit weighting software program…to assign weights to individual LEED credits. The final weights are expressed as a percentage and each credit point is fed into a typical LEED scorecard to arrive at a sum total of 100 pts for all the activity groups….certified, silver, gold or platinum require a 40%, 50%, 60%, or 80% achievement of pts."

LEED 2009 weighting can be described as a ten step process:

From: LEED 2009 – Weightings Overview.pdf

"1. Building impacts are estimated based on a building prototype.
2. Impacts are described with respect to 13 TRACI impact categories
3. Impacts are associated with up to 6 groups of credits (activity groups) – this assigns some number of potential points to groups of credits.
4. Points are allocated proportionally to credits within an activity group – the default is that each credit in the group contributes equally to the impact associated with the category and consequently receives an equal score.
5. Some credit weights are adjusted to reflect the relative performance of individual credits – this changes the distribution of points *within* a category (points in other groups are not changed)
6. Impact scores for each activity group are adjusted based on individual and aggregate capabilities of existing credits (e.g., control over transportation) – this means "uncontrolled" points from transportation are distributed proportionally across the other groups.
7. Credit weights for the 13 TRACI impact categories are integrated by taking a weighted average across all impact categories based on weights from the TRACI/BEES exercise.
8. Combined credit weights are rounded to the nearest whole number and the "residual" created during the rounded is tallied.
9. Residual points (i.e., points created by rounding) are manually reallocated across the system based on specific rules – the LSC directed that points be allocated with priority for greenhouse gas emissions reduction potential.
10. Results are transferred back to the existing scorecard for each system."

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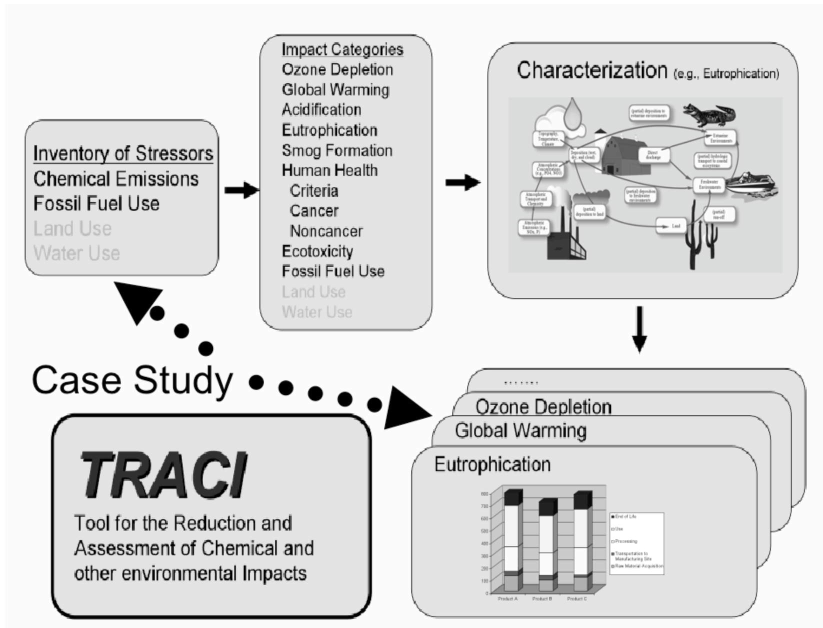

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Promoting Green Remediation

From: Scheuermann, K. *Feb 2.* 2009.

Bringing Sustainability to Our Site Clean-ups

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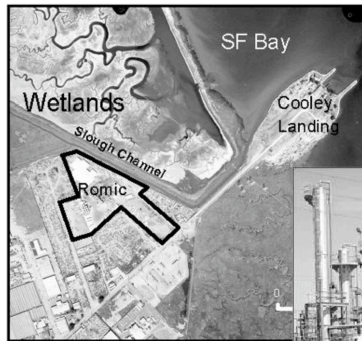
Romic East Palo Alto

From: Scheuermann, K. *Feb 2.* 2009.

• **14 acre hazardous waste management facility**

• **Soil and ground water contaminants are VOCs (such as TCE and PCE)**

• **Area of contamination to a depth of 80 feet**



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Remedy Alternatives at Romic

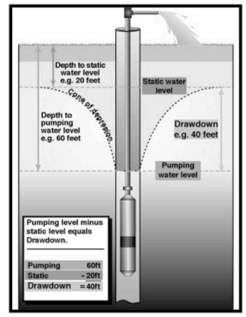
From: Scheuermann, K. *Feb 2.* 2009.

Bioremediation:

uses injections of cheese whey and molasses mixed with fresh water

Pump and Treat:

treatment of ground water in an air stripper followed by carbon filters



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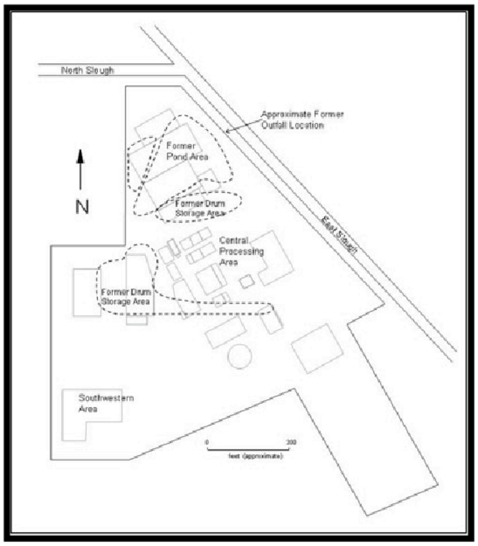
Remedy Alternatives at Romic

Modified from: Scheuermann, K., *Feb. 2. 2009.*



Alternative 2 (Hybrid)

Extraction wells *and* bioinjection wells

30 years to complete

Alternative 3 (Bioremediation)

Bioinjection wells only

10 years to complete

Alternative 4 (Pump and Treat)

Extraction wells only

40 years to complete

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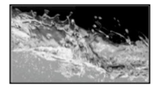
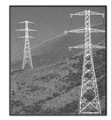
At Romic We Evaluated…

From: Scheuermann, K. *June 3*. 2009.



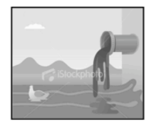
Resources and Energy Used

- **Water**
- **Construction Materials**
- **Electricity**
- **Fossil Fuel**



Wastes Generated

- **Spent Carbon**
- **Wastewater**



Air Emissions

- **NO_X, SO_X, PM, CO_2**

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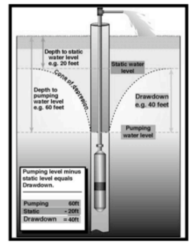
Level 1: On-Site Activities

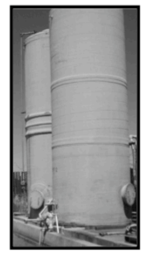
From: Scheuermann, K. *June 3.* 2009.

Well Construction



Groundwater Extraction

BioInjections



Groundwater Treatment

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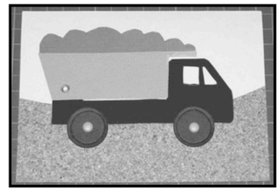
Level 2: Transport To & From Site

From: Scheuermann, K. *June 3.* 2009.

Operators to Site

Materials to Site



Wastes off Site

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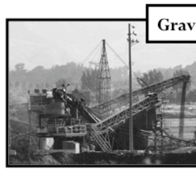
Level 3: Off-Site Manufacture

From: Scheuermann, K. *June 3.* 2009.

PVC Pipe Manufacture



Gravel Mining

Electricity Production

Cheese Whey Processing

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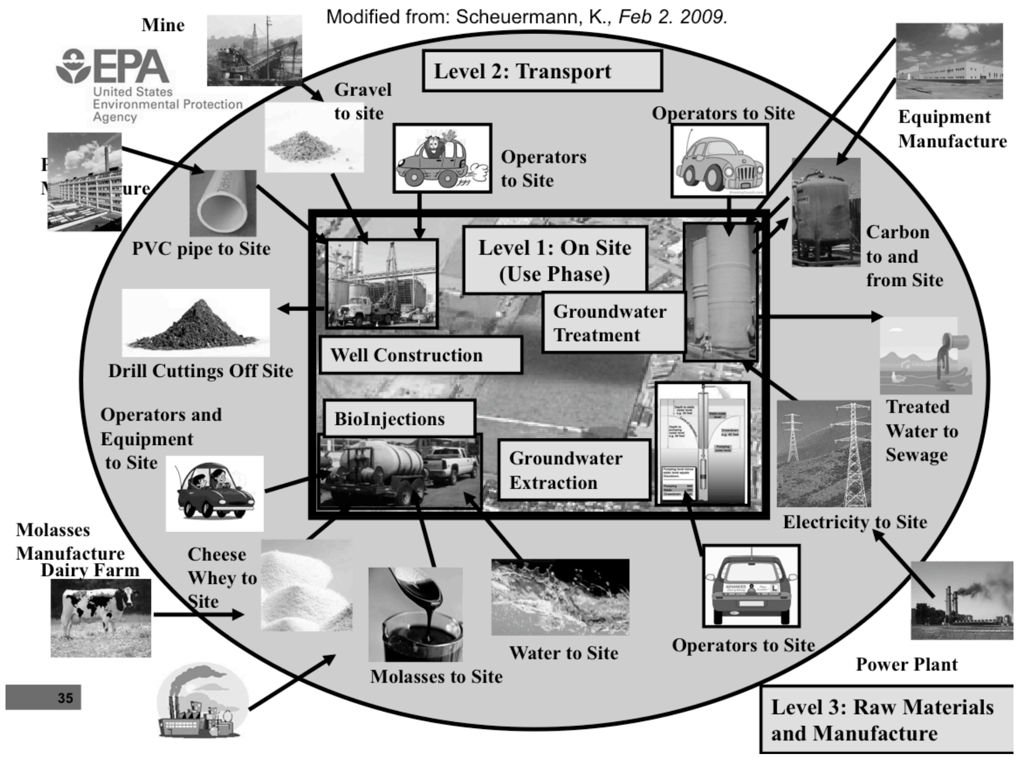
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Drill Cuttings Off Site
Well Construction
Treated Water to Sewage
Operators and Equipment to Site
BioInjections
Groundwater Extraction
Electricity to Site
Molasses Manufacture
Dairy Farm
Cheese Whey to Site
Water to Site
Operators to Site
Power Plant
Molasses to Site
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Level 3: Raw Materials and Manufacture

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Inventory Results.

Modified from: Scheuermann, K., Feb 2. *2009.*

	Alternative 2 Hybrid	Alternative 3 Bioremediation	Alternative 4 Pump and Treat
Materials			
PVC Pipe (lbs)	12,000	9,000	18,000
Cement (ft3)	60	70	30
Molasses (gallons)	180,000	220,000	0
Water (gallons)	5,700,000	6,800,000	0
Energy			
Diesel Fuel (gallons)	19,000	10,000	69,000
Gasoline (gallons)	12,000	8,000	9,000
Electricity (kWh)	6,000,000	20,000	32,000,000
Waste Generation			
Spent Carbon (lbs)	1,200,000	0	7,800,000
Wastewater (gallons)	500,000,000	0	2,700,000,000
Air Emissions			
CO_2 (tons)	3,000	200	15,000
Other			
Road Distance (miles)	300,000	200,000	600,000
Remediation Time (years)	30	10	40

- relatively high impact
- relatively low impact
- impacts similar (same order of magnitude)

- Alternative 3 looks better for most inventory items when considering on-site and transportation.

- Need to evaluate whether these inventory items and their offsite effects make a difference in impact assessment.

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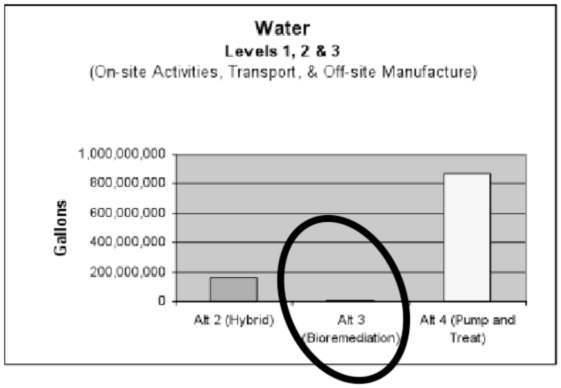
Results – Water

From: Scheuermann, K. *June 3.* 2009.



These values are for the life-time of each alternative remedy.

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Results – Water

From: Scheuermann, K. *June 3.* 2009.

Issues related to water:

- Water withdrawn *versus* water consumed.

- Water withdrawn in "water scarce" areas *versus* water withdrawn in "water abundant" areas.

- Potable *versus* non-potable water.

Maybe, not all water is equal… how should we take this into consideration?

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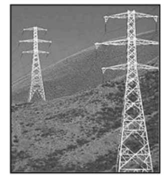
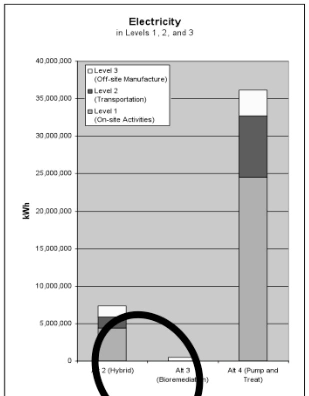
Results – Electricity

From: Scheuermann, K. *June 3.* 2009.





These values are for the life-time of each alternative remedy.

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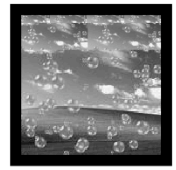
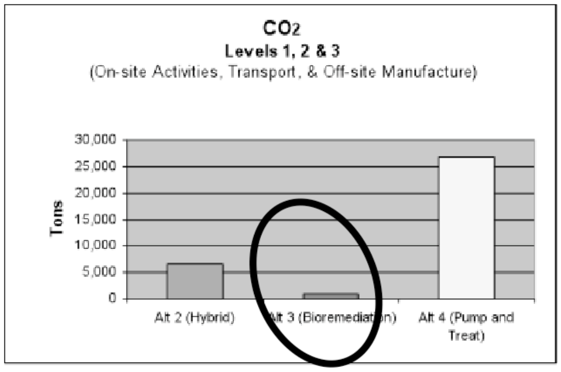
Results – CO_2 Emissions

From: Scheuermann, K. *June 3.* 2009.



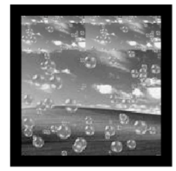


These values are for the life-time of each alternative remedy.

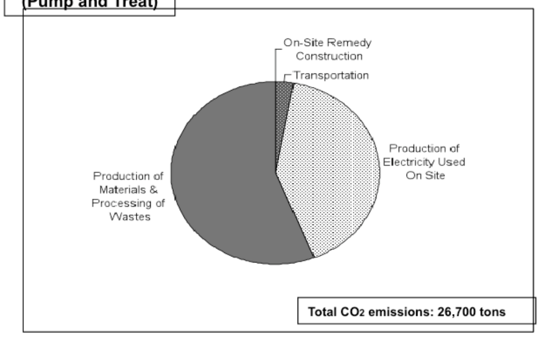
40

Results – CO_2 Emissions

From: Scheuermann, K. *June 3.* 2009.

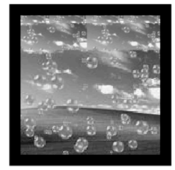


CO_2 Emissions Alternative 4 (Pump and Treat)



Off-site activities, even those not related to production of electricity used on-site, are a big part of the CO_2 footprint.

Region 9's Lessons Learned



- It is feasible to estimate the environmental footprint of a clean-up remedy.
- It is important to include off-site manufacturing in estimations of the environmental footprint.
- Need to identify which materials and activities contribute the greatest to the impact category (e.g., CO_2 footprint) and research them thoroughly.
- Need to consider the balance of: environmental assessment, timing of clean-up, and effectiveness of clean up.
- Even when the "best environmental option" is not selected, LCA can identify areas for improvement.
- A streamlined methodology and/or guidance would be helpful for conducting this type of analysis at other sites.

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References

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